Global Interferometric Skin-Friction Measurements on a Wingtip Model

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Skin-friction distribution on surfaces of flight vehicles is desirable for several reasons. Aerodynamicists would like to know where transition occurs and if separation is present. Turbulence modelers are interested in validating skin-friction (drag) predictions. Finally, if it were possible to sum the skin-friction distribution on a lifting wind tunnel model, it would be possible to determine the viscous contribution to the total drag, a quantity not readily measured independently of the induced drag. For these reasons research scientists have expended a great deal of energy in an ongoing effort to develop accurate, high-resolution skin-friction measurement techniques.

A high-resolution fringe-imaging skin-friction system (FISF) has been developed. Skin-friction measurements are made at points on an aerodynamic surface by imaging the flow of oil drops and applying lubrication theory to determine the skin-friction level. At the heart of this system is a wide-field digital camera capable of imaging 4096 × 4096 pixels. The system was recently tested on a wingtip model in the Flight Mechanics Laboratory's 3- by 4-Foot Indraft Wind Tunnel. Image data processing based on digital photogrammetry is a key component of the system and is the enabling technology that permitted the gathering of 2500 independent measurements of skin friction on a wing.

The figure shows the skin-friction magnitude on the suction side of a wingtip model from a Reynolds-averaged Navier–Stokes solver using a Baldwin–Barth turbulence model (left) compared with experimental measurements (right). This comparison shows reasonable agreement on the inboard portion of the wing where the flow is nearly two-dimensional. In the vicinity of the wingtip vortex (top-right corner), where the flow is highly three dimensional, substantial differences in the skin-friction magnitude are seen. These differences are attributed to the turbulence modeling deficiencies in the computed Navier–Stokes solution.

The FISF system described has recently been used in production tests of a Boeing 777 and also of a high-speed research model in the Ames 12-Foot Wind Tunnel.

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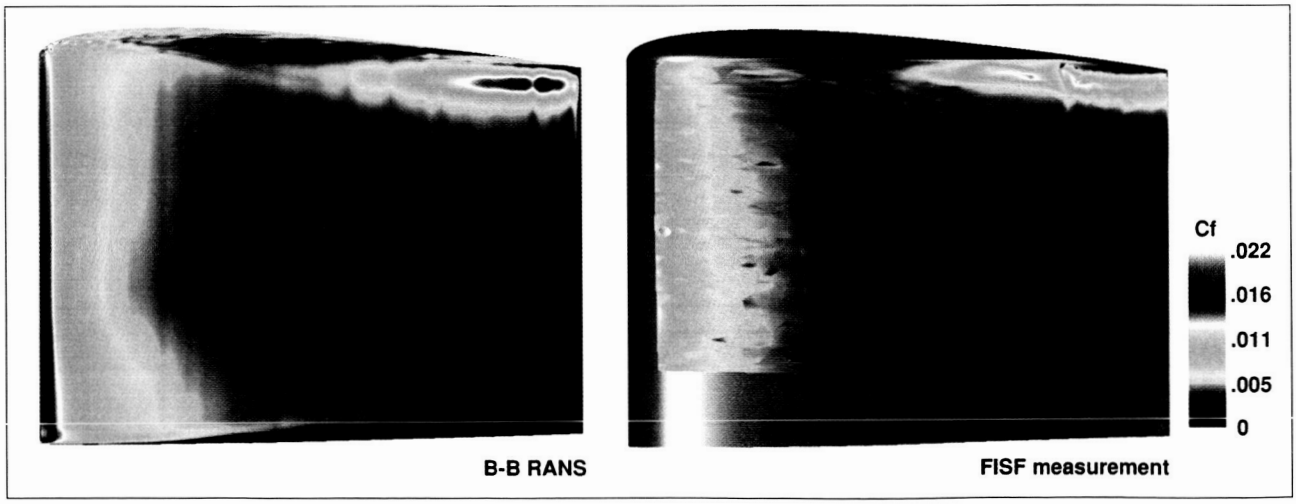

Fig. 1. Comparison of computed and measured skin friction on a wingtip (flow left to right).